



Advanced Combustion Technologies for Mobile and Stationary Engines



We are developing technologies to improve the efficiency of internal combustion engines and to reduce harmful emissions from the engine exhaust.

We are drawing upon Livermore's multidisciplinary capabilities to develop ways of increasing engine efficiency, thus saving fuel, while reducing the emissions that adversely affect the environment. Our efforts focus on analyzing alternative fuels, optimizing engine design, and applying innovative tools to clean the exhaust stream.

Underlying much of this work is the Laboratory's unique capability in chemical kinetic modeling, which uses computer simulation to determine how, when, and where combustion occurs within an engine and which chemical reactions occur.

Sponsors for this work include private industry, the Department of Energy, and the Department of Defense.

Alternative Diesel Fuels: Looking at Soot Production

In collaboration with several engine companies, we have been using these computer simulation techniques to study ignition and soot production in advanced diesel engines. Our chemical kinetic models examine how fuel molecular structure influences emissions. (Normal diesel fuel is a mixture of complex molecules with as many as 50 or more atoms per molecule.)

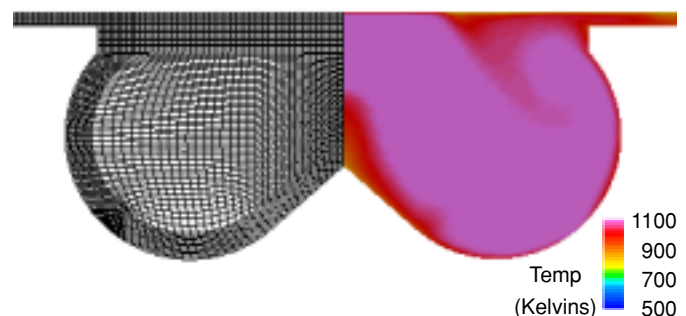
We are analyzing alternative fuels—such as dimethyl ether and dimethoxy methane—that reduce

soot and NO_x emissions from diesel engines. These fuels contain no carbon-to-carbon bonds and produce little or no soot; and, like other fuels containing oxygen atoms such as alcohols and ethers, they reduce NO_x emissions by lowering flame temperatures. We are using our chemistry models to understand and exploit these properties.

Our models are also being used to study ignition in both spark-ignited and diesel engines (where ignition occurs by compression) to learn how these processes vary with fuel molecular structure. These models are the most complex and detailed mechanisms available to study the chemical reactions of practical automotive fuels such as gasoline and diesel fuel.

Designing More Efficient Engines

We are exploring an innovative engine concept—Homogeneous Charge Compression Ignition (HCCI)—that promises to operate at high efficiency (greater than 40%) with low NO_x and particulate-matter emissions. In an HCCI engine, the fuel is premixed with air, as in a spark-ignited engine, but in a very “lean” mixture that has a high proportion of air to fuel. When the piston reaches its highest point, the fuel autoignites from compression, as in a diesel engine.



Temperature distribution before combustion in the combustion chamber of a Volkswagen TDI engine that has been converted to Homogeneous Charge Compression Ignition, at top dead center with the piston all the way up. For HCCI engines, temperature distribution in the cylinder is important in determining the burn duration and the emissions of hydrocarbons and carbon monoxide.

Mobile Applications

- Light-duty and medium-duty hybrid vehicles
- Heavy vehicles (trucks, buses)
- Locomotives

Stationary Applications

- Emergency generator sets
- Distributed generation



We have developed the capability to do very accurate analysis of HCCI combustion. We can predict all combustion parameters with good accuracy, and can also generate predictions for HCCI engine emissions. We also have an ongoing experimental effort to explore the operating range and the efficiency of the engine.

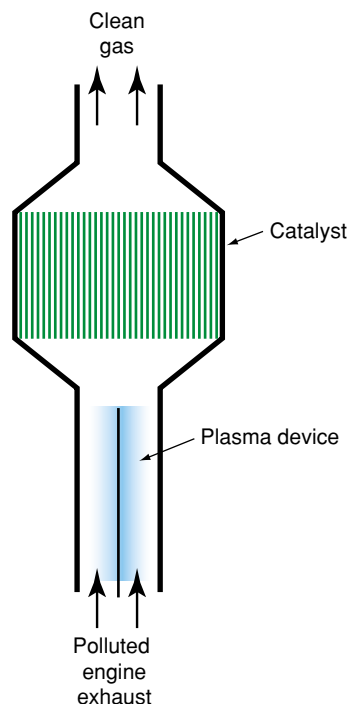
In other engine work, we designed and tested an engine to run on hydrogen fuel. Our goal was to get the most work per unit of fuel by designing for minimum heat transfer losses and timing losses, while also keeping emissions to a minimum. This engine would be suitable for constant-speed, constant-load situations, such as series hybrid-electric automobiles or home cogeneration systems. When driving a generator, it represents a low-cost alternative to the fuel cell.

Reducing NO_x Emissions from Lean-Burn Engines

Lean-burn engines are being viewed as one way to increase efficiency and burn less fuel, both in conventional gasoline engines and in diesel engines. However, because of high exhaust oxygen levels, lean-burn fuel mixtures create problems for catalytic converters now being used to reduce NO_x emissions. Either the oxygen dominates available conversion sites, thus slowing the NO_x conversion reactions, or the catalysts have poor durability.

Based on our experience in plasma physics and power supply technology, we have developed a process, Plasma Assisted Catalytic Reduction, that may solve this problem. We use a plasma device—essentially a metal wire, charged by a high-voltage pulsed power system, within a metal cylinder—to electrify the exhaust gas stream and break up the molecules as a “pretreatment” before the exhaust gas goes through a conventional lean-NO_x catalyst.

Changing the exhaust gas into plasma form converts NO molecules into NO₂ before the exhaust stream enters the catalyst, where the NO₂ molecules are then efficiently converted to benign N₂ and CO₂. Unlike conventional lean-NO_x catalysts, the NO_x reduction efficiency of plasma-assisted catalysts does not degrade in the presence of sulfur in the fuel.



The plasma device oxidizes NO and hydrocarbons to NO₂ and partially oxidized HCs before the exhaust stream goes to the catalyst, which reduces NO₂ and HCs to N₂, CO₂, and H₂O.

We have developed a bench-scale prototype of this plasma-assisted converter and have successfully run tests on the exhaust from a diesel engine and also on the controlled laboratory gases that simulate exhaust mixtures. We are now scaling the system up to handle the full exhaust flow from car and truck engines.

Such a system could potentially be applied to various types of vehicles with lean-burn engines, using either gasoline or diesel fuel, and also to diesel generators.

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